PA NT COOPERATION TREAT

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing: 28 September 2000 (28.09.00)	
International application No.: PCT/GB00/01074	Applicant's or agent's file reference: 57.0326WOPCT
International filing date: 21 March 2000 (21.03.00)	Priority date: 22 March 1999 (22.03.99)
Applicant: ROBERTSSON, Johan, Olof, Anders et al	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International preliminary Examining Authority on:

   04 August 2000 (04.08.00)

   [ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer: J. Zahra Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 57.0326WOPCT	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 b low.	
International application No. PCT/GB 00/ 01074	International filing date *(day/month/year)* 21/03/2000	(Earliest) Priority Date *(day/month/year)* 22/03/1999
Applicant SCHLUMBERGER HOLDINGS LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

      [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

      [ ] contained in the international application in written form.
      [ ] filed together with the international application in computer readable form.
      [ ] furnished subsequently to this Authority in written form.
      [ ] furnished subsequently to this Authority in computer readble form.
      [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
      [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has be n furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,

   [X] the text is approved as submitted by the applicant.
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   [X] the text is approved as submitted by the applicant.
   [ ] th text has been establish d, according to Rule 38.2(b), by this Authority as it appears in Box III. Th applicant may, within on month from th date of mailing of this international search report, submit comments to this Authority.

6. The figure of th **drawing** to be publish d with the abstract is Figure No. 8

   [X] as suggested by th applicant.
   [ ] because the applicant failed to suggest a figure.
   [ ] because this figure better characterizes th inv ntion.

   [ ] Non of the figures.

Form PCT/ISA/210 (first sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International Application No
P[illegible]GB 00/01074

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01V1/36 G01V1/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 486 865 A (RUEHLE WILLIAM H) 4 December 1984 (1984-12-04) abstract; claim 1 ---	1,12,18
P,X	GB 2 333 364 A (GECO AS) 21 July 1999 (1999-07-21) cited in the application	1,12,18
Y	abstract page 5, line 10 -page 6, line 5; figure 4 ---	9,13,19
Y	US 3 747 055 A (GREENE E) 17 July 1973 (1973-07-17) column 1, line 54 -column 2, line 14 column 2, line 54 - line 62 column 8, line 25 -column 9, line 8 abstract; figures 1-6 ---	9,13,19

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

30 June 2000

Date of mailing of the international search report

07/07/2000

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL – 2280 HV Rijswijk
Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,
Fax: (+31–70) 340–3016

Authorized officer

De Bekker, R

1

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	BARR F J ET AL: "ATTENUATION OF WATER-COLUMN REVERBERATIONS USING PRESSURE AND VELOCITY DETECTORS IN A WATER-BOTTOM CABLE" ANNUAL MEETING OF SOCIETY EXPL. GEOPHYS. EXPANDED ABSTRACTS,XX,XX, 1 January 1989 (1989-01-01), pages 653-656, XP000672198 the whole document figures 1-3 ---	1,12,18
A	US 4 979 150 A (BARR FREDERICK J) 18 December 1990 (1990-12-18) cited in the application abstract; figures 1-9,14 column 1, line 41 -column 2, line 31 column 2, line 57 -column 3, line 34 ---	1,12,18
A	AMUNDSEN L ET AL: "EXTRACTION OF THE NORMAL COMPONENT OF THE PARTICLE VELOCITY FROM MARINE PRESSURE DATA" GEOPHYSICS,US,SOCIETY OF EXPLORATION GEOPHYSICISTS. TULSA, vol. 60, no. 1, 1 January 1995 (1995-01-01), pages 212-222, XP000507558 ISSN: 0016-8033 abstract; figure 1 ** formula 20 ** ---	1,2,12, 18
A	GB 2 090 407 A (MOBIL OIL CORP) 7 July 1982 (1982-07-07) abstract; figures 1-5 page 1, left-hand column, line 63 -right-hand column, line 1 ---	1,12,18
A	US 2 757 356 A (HAGGERTY P.E.) 31 July 1956 (1956-07-31) figures 1-7 ---	3-7, 14-17, 20-23
A	US 4 222 266 A (THEODOULOU SAMUEL M) 16 September 1980 (1980-09-16) abstract --- -/--	7,8

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01074

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	SCHNEIDER W A ET AL: "A new data-processing technique for the elimination of ghost arrivals on reflection seismograms" GEOPHYSICS,US,SOCIETY OF EXPLORATION GEOPHYSICISTS. TULSA, vol. 29, no. 5, 1 October 1964 (1964-10-01), pages 783-805, XP002087819 ISSN: 0016-8033 figures 2,3	18
X	US 5 850 622 A (VASSILIOU ANTHONY A ET AL) 15 December 1998 (1998-12-15) figure 7	24-29

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/01074

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 4486865	A	04-12-1984	BR	8105589	A	18-05-1982
			CA	1157139	A	15-11-1983
			DE	3134325	A	06-05-1982
			FR	2489530	A	05-03-1982
			GB	2083221	A,B	17-03-1982
			SG	78384	G	26-04-1985
			AU	542118	B	07-02-1985
			AU	7407081	A	11-03-1982
			JP	57074676	A	10-05-1982
GB 2333364	A	21-07-1999	FR	2773618	A	16-07-1999
			NO	990153	A	16-07-1999
US 3747055	A	17-07-1973	NONE			
US 4979150	A	18-12-1990	AU	5716490	A	28-02-1991
			CA	2019007	A,C	25-02-1991
			DE	69018161	D	04-05-1995
			DE	69018161	T	07-09-1995
			EG	19158	A	29-02-1996
			EP	0414344	A	27-02-1991
			NO	303033	B	18-05-1998
GB 2090407	A	07-07-1982	US	4380059	A	12-04-1983
			CA	1254297	A	16-05-1989
			DE	3149525	A	08-07-1982
			NO	813463	A,B,	30-06-1982
US 2757356	A	31-07-1956	NONE			
US 4222266	A	16-09-1980	CA	1136255	A	23-11-1982
			GB	2029582	A,B	19-03-1980
US 5850622	A	15-12-1998	CA	2242757	A	14-05-1998
			EP	0873527	A	28-10-1998
			NO	983130	A	07-09-1998
			WO	9820367	A	14-05-1998

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

WANG, William L.
Intellectual Property Law ~~Dept.~~
Schlumberger Cambridge Research Ltd
High Cross
Madingley Road
Cambridge CB3 0EL
GRANDE BRETAGNE

PATENTS
DATE RECEIVED 09 FEB 2001
380
WLW

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

	Date of mailing *(day/month/year)* 08.02.2001
Applicant's or agent's file reference 57.0326WOPCT	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/01074	21/03/2000	22/03/1999

Applicant
SCHLUMBERGER HOLDINGS LIMITED et al.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Case No. 57.0326 WO PCT
Scan
Load
Activity ✗
Watchdog Dan.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Dekker, M Tel.+31 70 340-4046

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 57.0326WOPCT	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB00/01074	International filing date *(day/month/year)* 21/03/2000	Priority date *(day/month/year)* 22/03/1999
International Patent Classification (IPC) or national classification and IPC G01V1/36		
Applicant SCHLUMBERGER HOLDINGS LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   ☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☒ Certain documents cited
   VII ☒ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
04/08/2000	08.02.2001
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized officer De Bekker, R Telephone No. +31 70 340 4094

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/01074

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:

   Description, pages:

   1-20 as originally filed

   Claims, No.:

   1-29 as originally filed

   Drawings, sheets:

   1/13-13/13 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:

   ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-23
	No:	Claims	24-29
Inventive step (IS)	Yes:	Claims	1-23
	No:	Claims	24-29
Industrial applicability (IA)	Yes:	Claims	1-29
	No:	Claims	

2. Citations and explanations
   see separate sheet

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

and / or

2. Non-written disclosures (Rule 70.9)

   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Reference is made to the following documents:

- AMUNDSEN L ET AL: 'EXTRACTION OF THE NORMAL COMPONENT OF THE PARTICLE VELOCITY FROM MARINE PRESSURE DATA' GEOPHYSICS,US,SOCIETY OF EXPLORATION GEOPHYSICISTS. TULSA, vol. 60, no. 1, 1 January 1995 (1995-01-01), pages 212-222, XP000507558 ISSN: 0016-8033
- GB-A-2 333 364 (GECO AS) 21 July 1999 (1999-07-21) cited in the application
- US-A-5 850 622 (VASSILIOU ANTHONY A ET AL) 15 December 1998 (1998-12-15)

Part V:

Claim 1:
The Amundsen'95 document is regarded as representing the closest prior art to the claimed invention, it discloses the separation of up and down propagating components by combination of separate pressure data and filtered vertical particle motion data in which the filter is based in part on the velocity of sound in the fluid medium, the density of the fluid medium and the plurality of acquisition parameters (see pg.221, formula B-7).
The subject-matter of the claim differs from the Amundsen'95 in that the filter is considered to be a spatial filter which solves the objective problem of avoiding the need of calculating individual filters (angle dependent scaling factors) for each separate data trace. As a consequence this spatial filter renders it necessary to take several data points within a spatial area.
A spatial filtering process is also discussed in the Amundsen'95 (pg.216, par.: numerical example), however this process relates to a separate

embodiment relating to the derivation of the vertical particle motion by means of a solution of the Fredholm integral (formula 14, pg.215) and it therefore does not suggest the claimed solution.
Claim 1 therefore fulfils the novelty and inventive step requirements of Art.33(2)+(3) PCT.

Claims 2-11:
These claims define further embodiments of the invention defined in claim 1 and therefore also fulfil the requirements of Art.33(2)+(3) PCT.

Claim 12:
Since this claim defines a method corresponding to the method of claim , but involving the application of a spatial filter to the pressure-data, then this claim likewise fulfils the novelty and inventive step requirements of Art.33(2)+(3) PCT.

Claims 13-17:
These claims define further embodiments of the invention defined in claim 1 and therefore also fulfil the requirements of Art.33(2)+(3) PCT.

Claim 18:
Since this claim defines a method corresponding to the method of claim , but relating to multiple locations for the source events, then this claim likewise fulfils the novelty and inventive step requirements of Art.33(2)+(3) PCT.

Claims 19-23:
These claims define further embodiments of the invention defined in claim 1 and therefore also fulfil the requirements of Art.33(2)+(3) PCT.

Claim 24:
The subject-matter of this claim consists of a computer-readable medium which is suitable for storing a specific program and as such is considered to be anticipated by any computer-readable means, see eg. the diskette disclosed in Fig.7 of US'622. This claim does not therefore fulfil the novelty requirements of Art.33(2) PCT.

Claims 25-29:
For the same reasons given already for claim 24 these claims also do not meet the novelty requirements of Art.33(2) PCT.

Part VI:
GB'364 is an intermediate document with relevant subject-matter which will not be taken into account in the international phase in accordance with Rule 64.3 PCT.

Part VII:

Certain defects in the international application:

A discussion of Amundsen'95 should have been introduced into the description as required by Rule 5.1 (a)(ii) PCT.

In view of the nature of the claimed subject-matter the two part form does not appear to be appropriate.

Rule 5.1 (a)(iii) PCT requires that all claims should be in conformity with the description.

Part VIII:

The examiner considers the difference in phrasing in independent claims 1,12,18 referring to the pressure data representing at least the pressure in the fluid medium with respect to the phrasing referring to the vertical particle motion "representing at least the vertical particle motion of acoustic energy propagating in the fluid medium" misleading to the reader, since both of the data include acoustic energy.

It is noted that in the International Examination procedure a suggestion has been made to bring the phrasing into consistency by referring to the pressure data as to be representing "at least the pressure related to acoustic energy propagating in the fluid medium", to meet the requirements of Art.6 PCT.

PCT INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01V 1/36, 1/38	A1	(11) International Publication Number: **WO 00/57207** (43) International Publication Date: 28 September 2000 (28.09.00)

(21) International Application Number: PCT/GB00/01074

(22) International Filing Date: 21 March 2000 (21.03.00)

(30) Priority Data:
9906456.0 22 March 1999 (22.03.99) GB

(71) Applicant (*for all designated States except CA FR US*): SCHLUMBERGER HOLDINGS LIMITED [-/-]; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola (VG).

(71) Applicant (*for CA only*): SCHLUMBERGER CANADA LIMITED [CA/CA]; Monenco Place, 24th floor, 801 6th Avenue, S.W., Calgary, Alberta T2P 3W2 (CA).

(71) Applicant (*for FR only*): SERVICES PETROLIERS SCHLUMBERGER [FR/FR]; 42, rue Saint-Dominique, F-75007 Paris (FR).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): ROBERTSSON, Johan, Olof, Anders [SE/GB]; Stasjonsveien 28A, 0772 Oslo (NO). KRAGH, Julian, Edward [GB/GB]; Sudbury Cottage, Cornish Hall End Road, Little Sampford, Essex CB10 2QS (GB). MARTIN, James, Edward [GB/NO]; Brenneveien 95, N-1349 Rykkinn (NO).

(74) Agent: WANG, William, L.; Intellectual Property Law Department, Schlumberger Cambridge Research Limited, High Cross, Madingley Road, Cambridge CB3 0L (GB).

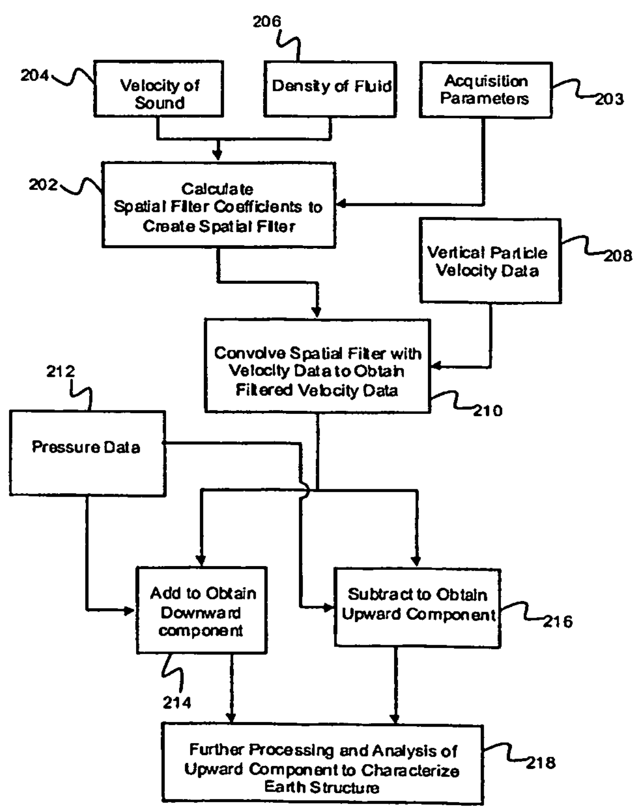
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: METHOD AND SYSTEM FOR REDUCING EFFECTS OF SEA SURFACE GHOST CONTAMINATION IN SEISMIC DATA

(57) Abstract

An improved de-ghosting method and system that utilises multi-component marine seismic data recorded in a fluid medium is disclosed. The disclosed method makes use of two types of data: pressure data, that represents the pressure in the fluid medium, such as sea water, at a number of locations; and vertical particle motion data, that represents the vertical particle motion of the acoustic energy propagating in the fluid medium at a number of locations within the same spatial area as the pressure data. The vertical particle motion data can be in various forms, for example, velocity, pressure gradient, displacement, or acceleration. A spatial filter is designed so as to be effective at separating up and down propagating acoustic energy over substantially the entire range of non-horizontal incidence angles in the fluid medium. The spatial filter is applied to either the vertical particle motion data or to the pressure data, and then combined with the other data to generate pressure data that has its up and down propagating components separated.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

Method and System For Reducing Effects of Sea Surface Ghost Contamination In Seismic Data

FIELD OF THE INVENTION:

The present invention relates to the field of reducing the effects of sea-surface ghost reflections in seismic data. In particular, the invention relates an improved de-ghosting method that utilises measurements or estimates of multi-component marine seismic data recorded in a fluid medium.

BACKGROUND OF THE INVENTION:

Removing the ghost reflections from seismic data is for many experimental configurations equivalent to up/down wavefield separation of the recorded data. In such configurations the down-going part of the wavefield represents the ghost and the up-going wavefield represents the desired signal. Exact filters for up/down separation of multi-component wavefield measurements in Ocean Bottom Cable (OBC) configurations have been derived by Amundsen and Ikelle, and are described in U.K. Patent Application Number 9800741.2. An example of such a filter corresponding to de-ghosting of pressure data at a frequency of 50 Hz for a seafloor with P-velocity of 2000 m/s, S-velocity of 500 m/s and density of 1800 kg/m3 is shown in Figure 2. At this frequency, the maximum horizontal wavenumber for P-waves right below the seafloor is $k=0.157\ m^{-1}$, whereas it is $k=0.628\ m^{-1}$ for S-waves. Notice the pole and the kink due to a zero in the filter at these two wavenumbers, making approximations necessary for robust filter implementations. Figure 3 shows approximations to the filter. These filters

are only good at wavenumbers smaller than the wavenumber where the pole occurs. Hence, energy with low apparent velocities (for instance S-waves or Scholte waves at the seafloor) will not be treated properly. Moreover, since they do not have a complex part, evanescent waves will also not be treated properly.

The OBC de-ghosting filters have been shown to work very well on synthetic data. However, apart from the difficulty with poles and zeros at critical wave numbers, they also require knowledge about the properties of the immediate sub-bottom locations as well as hydrophone/geophone calibration and coupling compensation.

A normal incidence approximation to the de-ghosting filters for data acquired at the sea floor was described by Barr, F.J. in U.S. Patent: 4,979,150, issued 1990, entitled 'System for attenuating water-column reflections', (hereinafter "Barr (1990)"). For all practical purposes, this was previously described by White, J.E., in a 1965 article entitled 'Seismic waves: radiation, transmission and attenuation', McGraw-Hill (hereinafter "White (1965)"). However, this technique is not effective when the angle of incidence is away from vertical. Also, this technique does not completely correct for wide-angle scattering and the complex reflections from rough sea surfaces. Additionally, its is believed that the OBC techniques described have not been used successfully in a fluid medium, such as with data gathered with towed streamers.

SUMMARY OF THE INVENTION:

Thus, it is an object of the present invention to provide a method of de-ghosting which improves attenuation of noise from substantially all non-horizontal angles of incidence.

It is an object of the present invention to provide a method of de-ghosting of seismic measurements made in a fluid medium which improves attenuation of the ghost as well as downward propagating noise from substantially all non-horizontal angles of incidence.

Also, it is an object of the present invention to provide a method of de-ghosting which is not critically dependent on knowledge about the properties of the surrounding fluid medium as well as hydrophone/geophone calibration and coupling compensation.

Also, it is an object of the present invention to provide a method of de-ghosting whose exact implementation is robust and can be implemented efficiently.

According to the invention, a method is described for sea surface ghost correction through the application of spatial filters to the case of marine seismic data acquired in a fluid medium. Using, for example, either typical towed streamer or vertical cable geometries. Preferably, both pressure and vertical velocity measurements are acquired along the streamer. The invention takes advantage of non-conventional velocity measurements taken along a marine towed streamer, for example. New streamer designs are currently under development and are expected to become commercially available in the near future. For example, the Defence Evaluation and Research Agency (DERA), based in

Dorset, U.K., claim to have successfully built such a streamer for high frequency sonar applications.

According to an alternative embodiment, the invention is also applicable to seismic data obtained with configurations of multiple conventional streamers. Here, the filters make use of vertical pressure gradient measurements, as opposed to velocity measurements. According to the invention, an estimate of the vertical pressure gradient can be obtained from over/under twin streamer data, or more generally from streamer data acquired by a plurality of streamers where the streamers are spatially deployed in a manner analogous to that described in U.K Patent Application Number 9820049.6, by Robertsson, entitled 'Seismic detection apparatus and related method" filed in 1998 (hereinafter "Robertsson (1998)"). For example, three streamers can be used, forming a triangular shape cross-section along their length. Vertical pressure gradient data can also be obtained from pressure gradient measuring devices.

According to the invention, the filters fully account for the rough sea perturbed ghost, showing improvement over other techniques based on normal incidence approximations (see e.g., White (1965)), which have been applied to data recorded at the sea floor.

Advantageously, according to preferred embodiments of the invention, the results are not sensitive to streamer depth, allowing the streamer(s) to be towed at depths below swell noise contamination, hence opening up the acquisition weather window where shallow towed streamer data would be unusable. Local streamer accelerations will be minimised in the deep water flow regime, improving resolution of the

pressure, multi-component velocity and pressure gradient measurements.

Advantageously, according to preferred embodiments of the invention, there are no filter poles in the data window, except for seismic energy propagating horizontally at the compressional wave speed in water.

Advantageously, according to preferred embodiments of the invention, the filter is not critically dependent on detailed knowledge of the physical properties of the surrounding fluid medium.

The filters can be simple spatial convolutions, and with the regular geometry of typical towed streamer acquisition the filters are efficient to apply in the frequency-wavenumber (FK) domain. The filters can also be formulated for application in other domains, such as time-space and intercept time-slowness (τ-p).

According to the invention, a method of reducing the effects in seismic data of downward propagating reflected and scattered acoustic energy travelling in a fluid medium is provided. The method advantageously makes use of two types of data: pressure data, that represents the pressure in the fluid medium, such as sea water, at a number of locations; and vertical particle motion data, that represents the vertical particle motion of the acoustic energy propagating in the fluid medium at a number of locations within the same spatial area as the pressure data. The distance between the locations that are represented by the pressure data and the vertical particle motion data in each case is preferably less than the Nyquist spatial sampling criterion. The vertical particle motion data can

be in various forms, for example, velocity, pressure gradient, displacement, or acceleration.

The spatial filter is created by calculating a number of coefficients that are based on the velocity of sound in the fluid medium and the density of the fluid medium. The spatial filter is designed so as to be effective at separating up and down propagating acoustic energy over substantially the entire range of non-horizontal incidence angles in the fluid medium.

The spatial filter is applied to either the vertical particle motion data or to the pressure data, and then combined with the other data to generate pressure data that has its up and down propagating components separated. The separated data are then processed further and analysed. Ordinarily the down-going data would be analysed, but the up going data could be used instead if the sea surface was sufficiently calm.

According to an alternative embodiment, a method of reducing the effects of downward propagating reflected and scattered acoustic energy travelling in a fluid medium is provided wherein the pressure data and vertical particle motion data represent variations caused by a first source event and a second source event. The source events are preferably generated by firing a seismic source at different locations at different times, and the distance between the locations is preferably less than the Nyquist spatial sampling criterion.

The present invention is also embodied in a computer-readable medium which can be used for directing an apparatus, preferably a computer, to reduce the effects in seismic data of downward propagating reflected and scattered

acoustic energy travelling in a fluid medium as otherwise described herein.

BRIEF DESCRIPTION OF THE DRAWINGS:

Figure 1 shows examples of simple seismic ray paths for primary events, and ghosts that are last reflected from the rough sea-surface;

Figure 2 shows an exact pressure de-ghosting filter for OBC data for a seafloor with P-velocity of 2000 m/s, S-velocity of 500 m/s and density of 1800 kg/m3; the upper panel shows the Real part of exact filter; and the lower panel shows the Imaginary part of exact filter;

Figure 3 shows the Real part of the exact OBC de-ghosting filter (in the solid line) shown in Figure 2, the first order Taylor approximation filter (in the plus line), and the first four fractional expansion approximations filters (in the dash-dotted lines);

Figure 4 illustrates the potential impact of 3D rough sea surface ghost reflection and scattering on consistency of the seismic data waveform;

Figure 5 illustrates the potential impact of the rough sea surface ghost perturbation on time-lapse seismic data quality;

Figures 6a-6f show various embodiments for data acquisition set-ups and streamer configurations according to preferred embodiments of the invention;

Figure 7 shows an exemplary two-dimensional spatial filter response (ω/k_z) for dx=6m;

Figure 8 is a flow chart illustrating some of the steps of the de-ghosting method for the combination of

pressure and vertical velocity data to achieve separated pressure data, according to a preferred embodiment of the invention;

Figure 9 schematically illustrates an example of a data processor that can be used to carry out preferred embodiments of the invention;

Figure 10 shows an example of a shot record computed below a 4m significant wave height (SWH) rough sea surface, the left panel shows pressure, and the right panel shows vertical velocity scaled by water density and the compressional wave speed in water;

Figure 11 illustrates de-ghosting results of the shot record in Figure 10, the left panel shows results using the vertical incidence approximation, and the right panel illustrates the exact solution;

Figure 12 illustrates an example of de-ghosting results in detail for a single trace at 330m offset corresponding to an arrival angle of about 37 degrees, the upper panel shows the vertical incidence approximation, and the lower panel shows the Exact solution; and

Figures 13a-b illustrate two possible examples of multi-component streamer design.

DETAILED DESCRIPTION OF THE INVENTION:

Figure 1 is a schematic diagram showing reflections between a sea surface (S), sea floor (W) and a target reflector (T). Various events that will be recorded in the seismogram are shown and are labelled according to the series of interfaces they are reflected at. The stars

indicate the seismic source and the arrowheads indicate the direction of propagation at the receiver. Events ending with 'S' were last reflected at the rough sea surface and are called receiver ghost events. Down-going sea-surface ghost reflections are an undesirable source of contamination, obscuring the interpretation of the desired up-going reflections from the earth's sub-surface.

Rough seas are a source of noise in seismic data. Aside from the often-observed swell noise, further errors are introduced into the reflection events by ghost reflection and scattering from the rough sea surface. The rough sea perturbed ghost events introduce errors that are significant for time-lapse seismic surveying and the reliable acquisition of repeatable data for stratigraphic inversion.

The effect of the rough sea is to perturb the amplitude and arrival time of the sea surface reflection ghost and add a scattering coda, or tail, to the ghost impulse. The impulse response can be calculated by finite difference or Kirchhoff methods (for example) from a scattering surface which represents statistically typical rough sea surfaces. For example, a directional form of the Pierson-Moskowitz spectrum described by Pierson, W.J. and Moskowitz, L., 1964 'A proposed Spectral Form for Fully Developed Wind Seas Based on the Similarity Theory of S. A. Kitaigorodskii' J. Geo. Res., 69, 24, 5181-5190, (hereinafter "Pierson and Moskowitz (1964)"), and Hasselmann, D. E., Dunckel, M. and Ewing, J.A., 1980 'Directional Wave Spectra Observed During JONSWAP 1973', J. Phys. Oceanography, v10, 1264-1280, (hereinafter "Hasselmann *et al*, (1980)"). Both the wind's speed and direction define

the spectra. The Significant Wave Height ("SWH") is the subjective peak to trough wave amplitude, and is about equal to 4 times the RMS wave height. Different realisations are obtained by multiplying the 2D surface spectrum by Gaussian random complex numbers.

Figure 4 shows an example of rough sea impulses along a 400m 2D line (e.g. streamer) computed under a 2m SWH 3D rough sea surface. The streamer shape affects the details of the impulses, and in this example the streamer is straight and horizontal. Figure 4 shows, from top to bottom: The ghost wavelet (white trough) arrival time, the ghost wavelet maximum amplitude, a section through the rough sea realisation above the streamer, and the computed rough sea impulses. The black peak is the upward travelling wave, which is unperturbed; the white trough is the sea ghost reflected from the rough sea surface. The latter part of the wavelet at each receiver is the scattering coda from increasingly more distant parts of the surface. Notice that the amplitude and arrival time ghost perturbations change fairly slowly with offset. The arrival time perturbations are governed by the dominant wavelengths in the sea surface, which are 100-200m for 2-4m SWH seas, and the amplitude perturbations are governed by the curvature of the sea surface which has an RMS radius of about 80m and is fairly independent of sea state. The diffraction coda appear as quasi-random noise following the ghost pulse.

The rough sea perturbations cause a partial fill and a shift of the ghost notch in the frequency domain. They also add a small ripple to the spectrum, which amounts to 1-2dB of error for typical sea states. In the post stack

domain this translates to an error in the signal that is about -20dB for a 2m SWH sea.

Figure 5 shows an example of how such an error can be significant for time-lapse surveys. The panel on the top left shows a post-stack time-migrated synthetic finite difference seismic section. The top middle panel shows the same data but after simulating production in the oil reservoir by shifting the oil water contact by 6m and introducing a 6m partial depletion zone above this. The small difference is just noticeable on the black leg of the reflection to the right of the fault just below 2s two-way travel-time. The panel on the right (top) shows the difference between these two sections multiplied by a factor of 10. This is the ideal seismic response from the time-lapse anomaly.

The left and middle bottom panels show the same seismic sections, but rough sea perturbations for a 2m SWH (as described above) have been added to the raw data before processing. Note that different rough sea effects are added to each model to represent the different seas at the time of acquisition. The difference obtained between the two sections is shown on the bottom right panel (again multiplied by a factor of 10). The errors in the reflector amplitude and phase (caused by the rough sea perturbations) introduce noise of similar amplitude to the true seismic time-lapse response. To a great extent, the true response is masked by these rough sea perturbations. A method for correcting these types of error is clearly important in such a case, and with the increasing requirement for higher quality, low noise-floor data, correction for the rough sea ghost becomes necessary even in modest sea states.

Equation (1) gives the frequency domain expression for a preferred filter relating the up-going pressure field, $p^u(x)$, to the total pressure, $p(x)$, and vertical particle velocity, $v_z(x)$.

$$p^u(x) = 0.5\left[p(x) + \frac{\rho\omega}{k_z} * v_z(x)\right] \qquad (1)$$

where k_z is the vertical wavenumber for compressional waves in the water, ρ is the density of water and * denotes spatial convolution.

The vertical wavenumber is calculated from $k_z^2=k^2-k_x^2$ for two-dimensional survey geometries, or $k_z^2=k^2-k_x^2-k_y^2$ for three-dimensional survey geometries, with $k^2=\omega^2/c^2$, where c is the compressional wave speed in the water and k_x is the horizontal wavenumber for compressional waves in the water. The regular sampling of typical towed streamer data allows k_z to be calculated efficiently in the FK domain. Figure 7 shows an example of the filter response, ω/k_z for dx=6m (the filter is normalised for the display to an arbitrary value). Infinite gain poles occur when k_z is zero. This corresponds to energy propagating horizontally (at the compressional wave speed in water). For towed streamer data, there is little signal energy with this apparent velocity, any noise present in the data with this apparent velocity should be filtered out prior to the filter application, or, the filter should be tapered at the poles prior to application to avoid amplification of the noise.

The traditional filter (White (1965), Barr, (1990)) is equation (2):

$$p^{u} = 0.5[p + \rho c\, v_z] \qquad (2)$$

By comparison to equation (1), we see that this is a normal incidence approximation, which occurs when k_x is zero. This is implemented as a simple scaling of the vertical velocity trace followed by its addition to the pressure trace.

Equation (1) can also be formulated in terms of the vertical pressure gradient (dp(x)/dz). The vertical pressure gradient is proportional to the vertical acceleration:

$$dp(x)/dz = \rho\, dv_z(x)/dt \qquad (3)$$

Integrating in the frequency domain through division of iω, and substituting in equation (1) gives:

$$p^{u}(x) = 0.5\left[p(x) + \frac{1}{ik_z} * dp(x)/dz\right] \qquad (4)$$

Figures 6a-6f show various embodiments for data acquisition set-ups and streamer configurations according to preferred embodiments of the invention. Figure 6a shows a seismic vessel 120 towing a seismic source 110 and a seismic streamer 118. The sea surface is shown by reference number 112. In this example, the depth of streamer 118 is about 60 meters, however those of skill in the art will recognise

that a much shallower depth would ordinarily be used such as 6-10 meters. The dashed arrows 122a-d show paths of seismic energy from source 110. Arrow 122a shows the initial down-going seismic energy. Arrow 122b shows a portion of the seismic energy that is transmitted through the sea floor 114. Arrow 122c shows an up-going reflection. Arrow 122d shows a down-going ghost reflected from the surface. According to the invention, the down-going rough sea receiver ghost 122d can be removed from the seismic data.

Figures 6b-6f show greater detail of acquisition set-ups and streamer configurations, according to the invention. Figure 6b shows a multi-component streamer 124. The streamer 124 comprises multiple hydrophones (measuring pressure) 126a, 126b, and 126c, and multiple 3C geophones (measuring particle velocity in three directions x, y, and z) 128a, 128b, and 128c. The spacing between the hydrophones 126a and 126b, and between geophones 128a and 128b is shown to be less than 12 meters. Additionally, the preferred spacing in relation to the frequencies of interest is discussed in greater detail below.

Figure 6c shows a streamer 130 that comprises multiple hyrdophones 132a, 132b, and 132c, and multiple pressure gradient measuring devices 134a, 134b, and 134c. The spacing between the hydrophones 132a and 132b, and between pressure gradient measuring devices 134a and 134b is shown to be less than 12 meters.

Figure 6d shows a multi-streamer configuration that comprises hydrophone streamers 140a and 140b. The streamers comprise multiple hyrdophones 142a, 142b, and 142c in the case of streamer 140a, and 142d, 142e, and 142f in the case of streamer 140b. The spacing between the

hydrophones is shown to be less than 12 meters. The separation between steamers 140a and 140b in the example shown in Figure 6d is less then 2 meters. Although the preferred separation is less than 2 meters, greater separations are contemplated as being within the scope of the invention. Figure 6e shows a cross sectional view of a dual streamer arrangement. Figure 6f shows a multi-streamer configuration comprising three hydrophone streamers 140a, 140b, and 140c.

Adequate spatial sampling of the wavefield is highly preferred for the successful application of the de-ghosting filters. For typical towed streamer marine data, a spatial sampling interval of 12m is adequate for all incidence angles. However, to accurately spatially sample all frequencies up to 125Hz (for all incidence angles), a spatial sampling interval of 6.25 meters is preferred. These spacings are determined according to the Nyquist spatial sampling criterion. Note that if all incidence angles are not required, a coarser spacing than described above can be used. The filters can be applied equally to both group formed or point receiver data.

Figure 8 is a flow chart illustrating some of the steps of the de-ghosting method for the combination of pressure and vertical velocity data to achieve separated pressure data, according to a preferred embodiment of the invention. In step 202, spatial filter coefficients are calculated. The coefficients are preferably dependent on the characteristics of the acquisition parameters 203 (such as the temporal sample interval of the pressure and particle motion data, the spatial separation of the vertical particle motion measuring devices, and the spatial aperture of the

filter), the density of the fluid medium 206, and the speed of the compressional wave in the fluid medium (or velocity of sound) 204. Vertical particle motion data 208 and pressure data 212 are received, typically stored as time domain traces on a magnetic tape or disk. In step 210, the vertical particle motion data 208 are convolved in with the spatial filter to yield filtered vertical particle motion data. In step 214 the filtered vertical particle motion data are added to pressure data 212 to give the downward propagating component of the separated pressure data. Alternatively, in step 216 the filtered vertical particle motion data are subtracted from pressure data 212 to give the upward propagating component of the separated pressure data. Finally, in step 218 the upward component is further processes and analysed.

The processing described herein is preferably performed on a data processor configured to process large amounts of data. For example, Figure 9 illustrates one possible configuration for such a data processor. The data processor typically consists of one or more central processing units 350, main memory 352, communications or I/O modules 354, graphics devices 356, a floating point accelerator 358, and mass storage devices such as tapes and discs 360. It will be understood by those skilled in the art that tapes and discs 360 are computer-readable media that can contain programs used to direct the data processor to carry out the processing described herein.

Figure 10 shows a shot record example, computed under a 4m Significant Wave Height (SWH) sea and using the finite-difference method described by Robertsson, J.O.A., Blanch, J.O. and Symes, W.W., 1994 'Viscoelastic finite-

difference modelling' Geophysics, 59, 1444-1456 (hereinafter "Robertsson *et al.* (1994)") and Robertsson, J.O.A., 1996 'A Numerical Free-Surface Condition for Elastic/Viscoelastic Finite-difference modelling in the Presence of Topography', *Geophysics, 61, 6, 1921-1934* (hereinafter "Robertsson (1996)"). The streamer depth in this example is 60m. The left panel shows the pressure response and the right panel shows the vertical velocity response scaled by the water density and the compressional wave speed in water. A point source 50Hz Ricker wavelet was used and the streamer depth was 60m in this example. The choice of streamer depth allows a clear separation of the downward travelling ghost from the upward travelling reflection energy for visual clarity of the de-ghosting results. The trace spacing on the plot is 24m. A single reflection and its associated ghost are shown, along with the direct wave travelling in the water layer. Perturbations in the ghost wavelet and scattering noise from the rough sea surface are evident.

Figure 11 shows the results of de-ghosting the shot record shown in Figure 10. The left panel shows the result using the normal incidence approximation and the right panel shows the result using the exact solution. The exact solution shows a consistent response over all offsets, whereas the normal incidence approximation starts to break down at incident angles greater than about 20 degrees, and shows a poorer result at the near offsets. Note that the direct wave is not amplified by the exact filter application even though the poles of the filter lie close to its apparent velocity. The exact filter is tapered before application such that it is has near unity response for frequencies and wavenumbers corresponding to apparent

velocities of 1500m/s and greater. The weak event just below the signal reflection is a reflection from the side absorbing boundary of the model. It is upward travelling and hence untouched by the filter.

Figure 12 shows details of the de-ghosted results for a single trace from Figure 11. The trace offset is 330m corresponding to a 37 degree incidence angle. The upper panel shows the normal incidence approximation, and the lower panel shows the exact solution. Not only does the exact solution provide a superior result in terms of the de-ghosting, but also in terms of amplitude preservation of the signal reflection - the upper panel shows loss of signal amplitude after the de-ghosting.

The filters described herein are applicable to, for example, measurements of both pressure and vertical velocity along the streamer. Currently, however, only pressure measurements are commercially available. Therefore, engineering of streamer sections that are capable of commercially measuring vertical velocity is preferred in order to implement the filters.

Figures 13a-b illustrate two possible examples of multi-component streamer design. Figure 13a shows a coincident pressure and single 3-component geophone. In this design, the 3-component geophone is perfectly decoupled from the streamer. Figure 13b shows a coincident pressure and twin 3-component geophones. In this design, one of the 3-component geophones is decoupled from the streamer, the other is coupled to the streamer; measurements from both are combined to remove streamer motion from the data.

In an alternative formulation, the filters make use of vertical pressure gradient measurements. An estimate

of vertical pressure gradient can be obtained from over/under twin streamers (such as shown in Figures 6d and 6e) and multiple streamers (such as shown in Figure 6f) deployed in configurations analogous to that described in Robertsson (1998), allowing the filters to be directly applied to such data. However, for the results to remain sufficiently accurate, the streamers should not be vertically separated by more than 2m for seismic frequencies below approximately 80Hz.

An important advantage of multiple streamer configurations such as shown in Figure 6f is that their relative locations are less crucial than for over/under twin streamer geometries, where the two streamers are preferably directly above one another.

The filters described here are applied in 2D (along the streamer) to data modelled in 2D. The application to towed streamer configurations naturally lends itself to this implementation, the cross-line (streamer) sampling of the wavefield being usually insufficient for a full 3D implementation. Application of these filters to real data (with ghost reflections from 3D sea surfaces) will give rise to residual errors caused by scattering of the wavefield from the cross-line direction. This error increases with frequency though is less than 0.5dB in amplitude and 3.6° in phase for frequencies up to 150Hz, for a 4m SWH sea. These small residual noise levels are acceptable when time-lapse seismic surveys are to be conducted.

Invoking the principle of reciprocity, the filters can be applied in the common receiver domain to remove the downward travelling source ghost. Reciprocity simply means

that the locations of source and receiver pairs can be interchanged,(the ray path remaining the same) without altering the seismic response. Figure 1 can also be used to define the source ghost if the stars are now regarded as receivers and the direction of the arrows is reversed, with the source now being located at the arrow. This application is particularly relevant for data acquired using vertical cables, which may be tethered, for example, to the sea floor, or suspended from buoys. In the case of Figure 6a, those of skill in the art will understand that as the seismic vessel 120 travels though the water, the firing position of source 110 will change. The different positions of source 110 can be then be used to construct data in the common receiver domain as is well known in the art.

While preferred embodiments of the invention have been described, the descriptions and figures are merely illustrative and are not intended to limit the present invention.

CLAIMS

What is claimed is:

1. A method of reducing the effects in seismic data of downward propagating reflected and scattered acoustic energy travelling in a fluid medium comprising the steps of:

receiving pressure data representing at least the pressure in the fluid medium at a first location and a second location, the first location being in close proximity to the second location;

receiving vertical particle motion data representing at least the vertical particle motion of acoustic energy propagating in the fluid medium at a third location and a fourth location, the third location being in close proximity to the fourth location, and the first, second, third and fourth locations being within a spatial area;

calculating a plurality of spatial filter coefficients based in part on the velocity of sound in the fluid medium, the density of the fluid medium and a plurality of acquisition parameters, thereby creating a spatial filter which is designed so as to be effective at separating up and down propagating acoustic energy over a range of non-vertical incidence angles in the fluid medium;

applying the spatial filter to the vertical particle motion data to generate filtered particle motion data;

combining the filtered particle motion data with the pressure data to generate separated pressure data, the separated pressure data having up and down propagating components separated; and

analysing at least part of the up or down propagating component of the separated pressure data.

2. The method of claim 1 wherein the acquisition parameters include the temporal sampling interval, the spatial sampling interval, and the number of independent locations at which the pressure and vertical particle motion data are measured.

3. The method of claim 1 wherein the vertical particle motion data is measured using one or more multi-component streamers.

4. The method of claim 1 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the particle velocity of the acoustic energy.

5. The method of claim 1 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the vertical pressure gradient of the acoustic energy.

6. The method of claim 5 wherein the pressure gradient is measured using at least two parallel streamer cables in close proximity and vertically offset from one another.

7. The method of claim 1 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the vertical displacement of the acoustic energy.

8. The method of claim 1 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the vertical acceleration of the acoustic energy.

9. The method of claim 1 wherein the distance between the first location and the second location and the distance between the third location and the fourth location is less than the Nyquist spatial sampling criterion.

10. The method of claim 9 wherein the spatial area is substantially a portion of a line, and the range of non-vertical incidence angles includes substantially all non-horizontal incidence angles within a vertical plane that passes through the portion of line.

11. The method of claim 9 wherein the spatial area is a portion of a substantially planar region, and the range of non-vertical incidence angles include substantially all non-horizontal incidence angles.

12. A method of reducing the effects in seismic data of downward propagating reflected and scattered

acoustic energy travelling in a fluid medium comprising the steps of:

receiving pressure data representing at least the pressure in the fluid medium at a first location and a second location, the first location being in close proximity to the second location;

receiving vertical particle motion data representing at least the vertical particle motion of acoustic energy propagating in the fluid medium at a third location and a fourth location, the third location being in close proximity to the fourth location, and the first, second, third and fourth locations being within a spatial area;

calculating a plurality of spatial filter coefficients based in part on the velocity of sound in the fluid medium and the density of the fluid medium, thereby creating a spatial filter which is designed so as to be effective at separating up and down propagating acoustic energy over a range of non-horizontal incidence angles in the fluid medium;

applying the spatial filter to the pressure data to generate filtered pressure data;

combining the filtered pressure data with the vertical particle motion data to generate separated pressure data, the separated pressure data having up and down propagating components separated; and

analysing at least part of the up or down propagating component of the separated pressure data.

13. The method of claim 12 wherein the distance between the first location and the second location and the distance between the third location and the fourth location is less than the Nyquist spatial sampling criterion.

14. The method of claim 12 wherein the vertical particle motion data is measured using one or more multi-component streamers.

15. The method of claim 12 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the particle velocity of the acoustic energy.

16. The method of claim 12 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the vertical pressure gradient of the acoustic energy.

17. The method of claim 16 wherein the pressure gradient is measured using at least two parallel streamer cables in close proximity and vertically offset from one another.

18. A method of reducing the effects in seismic data of downward propagating reflected and scattered acoustic energy travelling in a fluid medium comprising the steps of:

receiving pressure data representing at least variations in pressure in the fluid medium at a first location, the variations caused in part by a first

source event and a second source event, the first source event and the second source event being within a spatial area;

receiving vertical particle motion data representing at least the vertical particle motion of acoustic energy propagating in the fluid medium at a second location, the acoustic energy being caused in part by the first source event and the second source event;

calculating a plurality of spatial filter coefficients based in part on the velocity of sound in the fluid medium and the density of the fluid medium, thereby creating a spatial filter which is designed so as to be effective at separating up and down propagating acoustic energy from the first source event and second source event over a range of non-horizontal incidence angles in the fluid medium;

applying the spatial filter to the vertical particle motion data to generate filtered particle motion data;

combining the filtered particle motion data with the pressure data to generate separated pressure data, the separated pressure data having up and down propagating components separated; and

analysing at least part of the up or down propagating component of the separated pressure data.

19. The method of claim 18 wherein the first source event and the second source event are generated by firing a seismic source at different locations at different times, and the distance between the location of the first

source event and the location of the second source event is less than the Nyquist spatial sampling criterion.

20. The method of claim 18 wherein the vertical particle motion data is measured using one or more multi-component streamers.

21. The method of claim 18 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the particle velocity of the acoustic energy.

22. The method of claim 18 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the vertical pressure gradient of the acoustic energy.

23. The method of claim 22 wherein the pressure gradient is measured using at least two parallel streamer cables in close proximity and vertically offset from one another.

24. A computer-readable medium which can be used for directing an apparatus to reduce the effects in seismic data of downward propagating reflected and scattered acoustic energy travelling in a fluid medium comprising:

means for retrieving pressure data representing at least the pressure in the fluid medium at a first location and a second location, the first location being in close proximity to the second location;

means for retrieving vertical particle motion data representing at least the vertical particle motion of acoustic energy propagating in the fluid medium at a third location and a fourth location, the third location being in close proximity to the fourth location, and the first, second, third and fourth locations being within a spatial area;

means for calculating a plurality of spatial filter coefficients based in part on the velocity of sound in the fluid medium, the density of the fluid medium and a plurality of acquisition parameters, thereby creating a spatial filter which is designed so as to be effective at separating up and down propagating acoustic energy over a range of non-vertical incidence angles in the fluid medium;

means for applying the spatial filter to the vertical particle motion data to generate filtered particle motion data;

means for combining the filtered particle motion data with the pressure data to generate separated pressure data, the separated pressure data having up and down propagating components separated; and

means for analysing at least part of the up or down propagating component of the separated pressure data.

25. The computer-readable medium of claim 24 wherein the distance between the first location and the second location and the distance between the third location

and the fourth location is less than the Nyquist spatial sampling criterion.

26. The computer-readable medium of claim 24 wherein the vertical particle motion data is measured using one or more multi-component streamers.

27. The computer-readable medium of claim 24 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the particle velocity of the acoustic energy.

28. The computer-readable medium of claim 24 wherein the vertical particle motion of the acoustic energy represented in said vertical particle motion data is the vertical pressure gradient of the acoustic energy.

29. The computer-readable medium of claim 28 wherein the pressure gradient is measured using at least two parallel streamer cables in close proximity and vertically offset from one another.

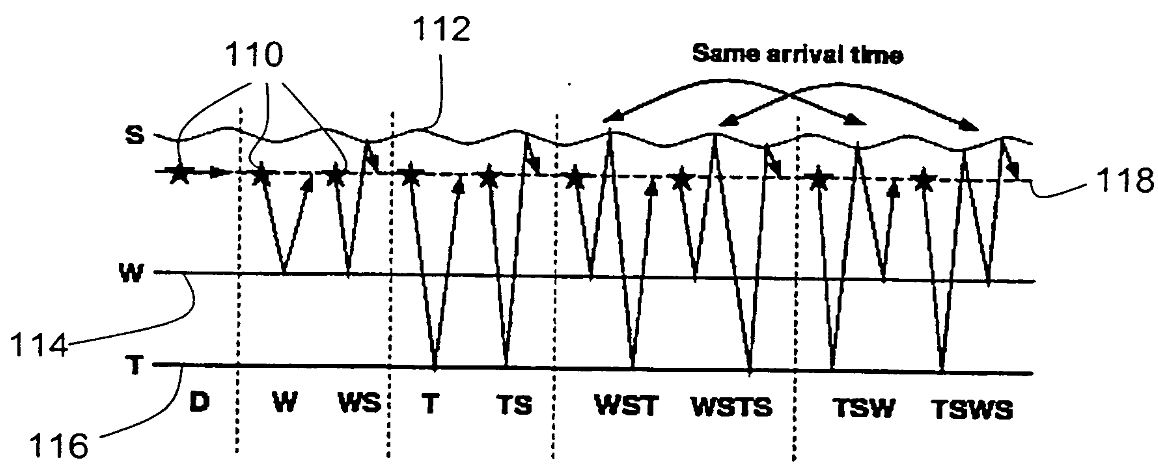

110
112
Same arrival time
S
W
T
118
114
116
D
W
WS
T
TS
WST
WSTS
TSW
TSWS

Figure 1

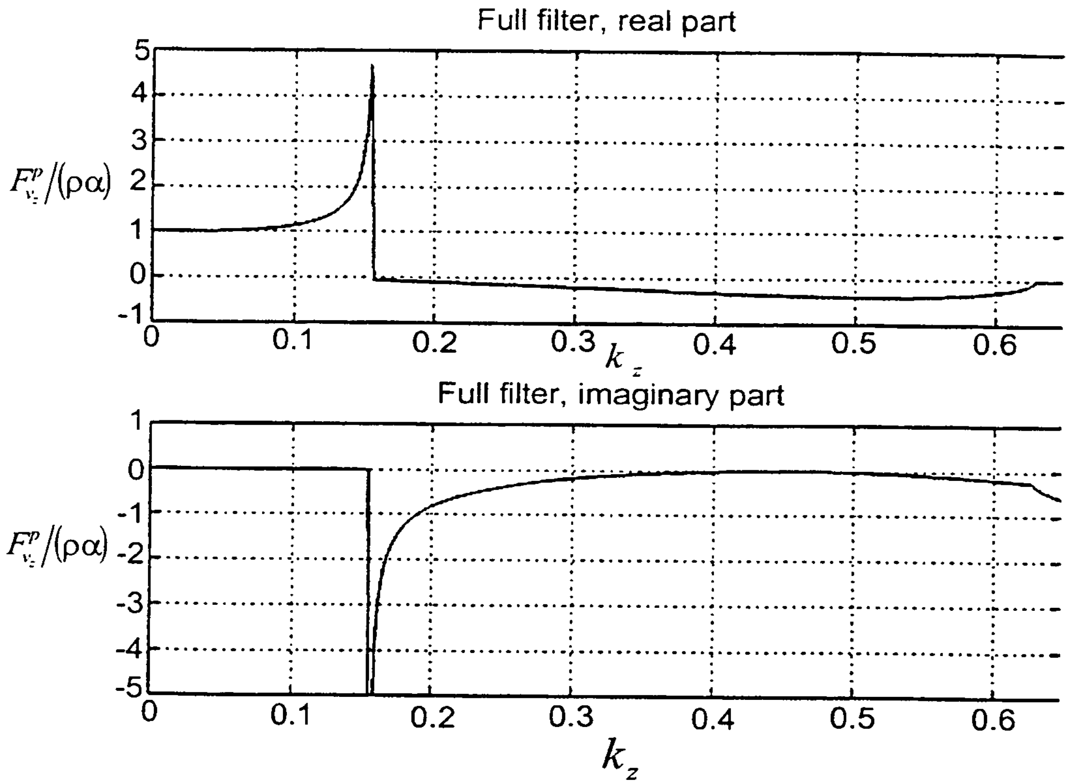


Figure 2 (prior art)

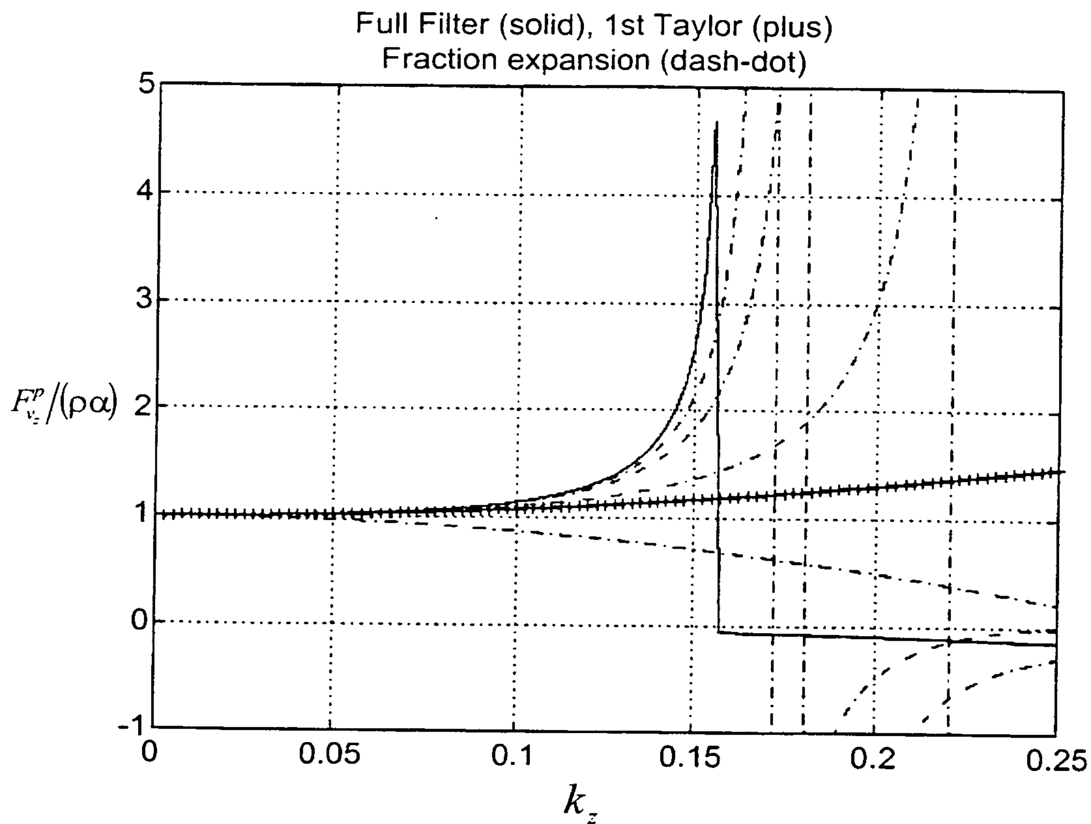


Figure 3 (prior art)

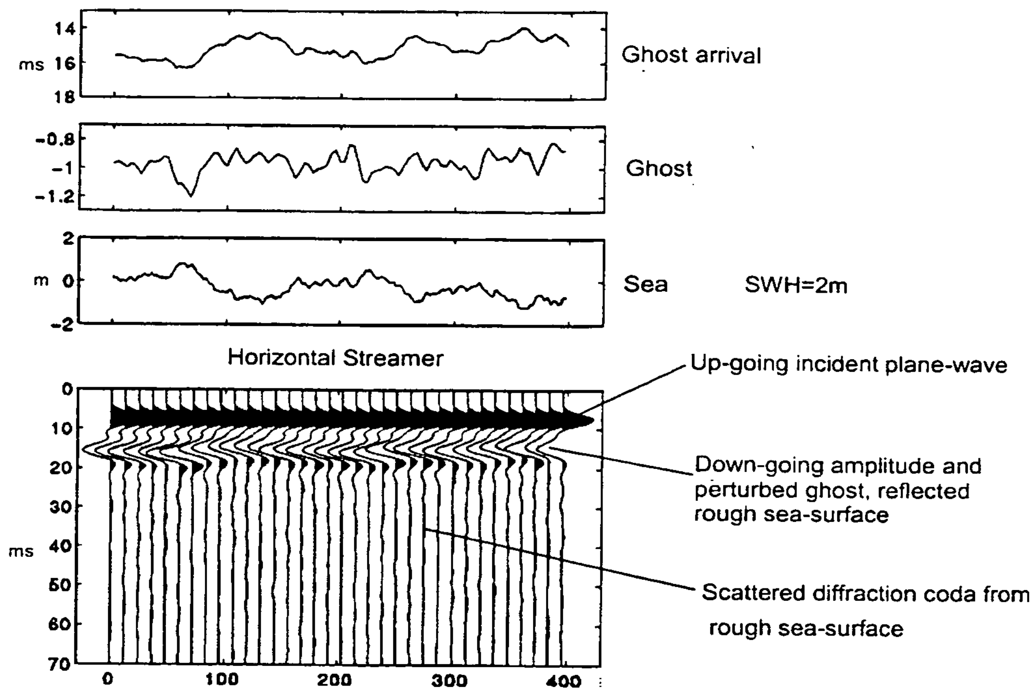

14
ms 16
18
Ghost arrival
-0.8
-1
-1.2
Ghost
2
m 0
-2
Sea
SWH=2m
Horizontal Streamer
0
10
20
30
ms 40
50
60
70
0
100
200
300
400
Up-going incident plane-wave
Down-going amplitude and perturbed ghost, reflected rough sea-surface
Scattered diffraction coda from rough sea-surface

Figure 4

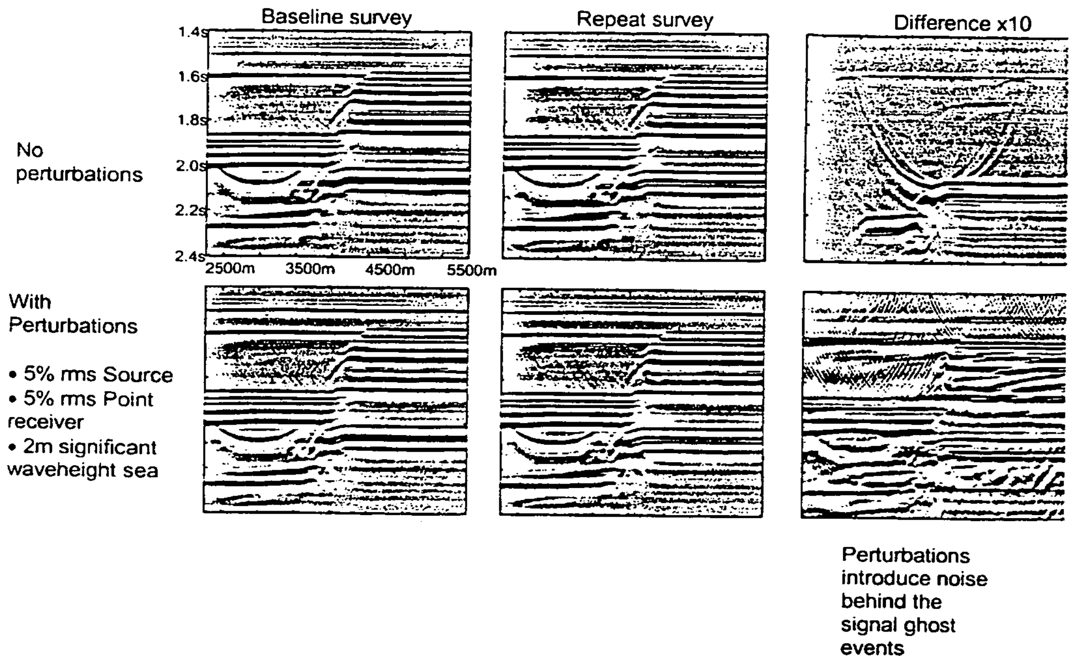

Baseline survey
Repeat survey
Difference x10
1.4s
1.6s
1.8s
2.0s
2.2s
2.4s
2500m
3500m
4500m
5500m
No perturbations
With Perturbations
• 5% rms Source
• 5% rms Point receiver
• 2m significant waveheight sea
Perturbations introduce noise behind the signal ghost events

Figure 5

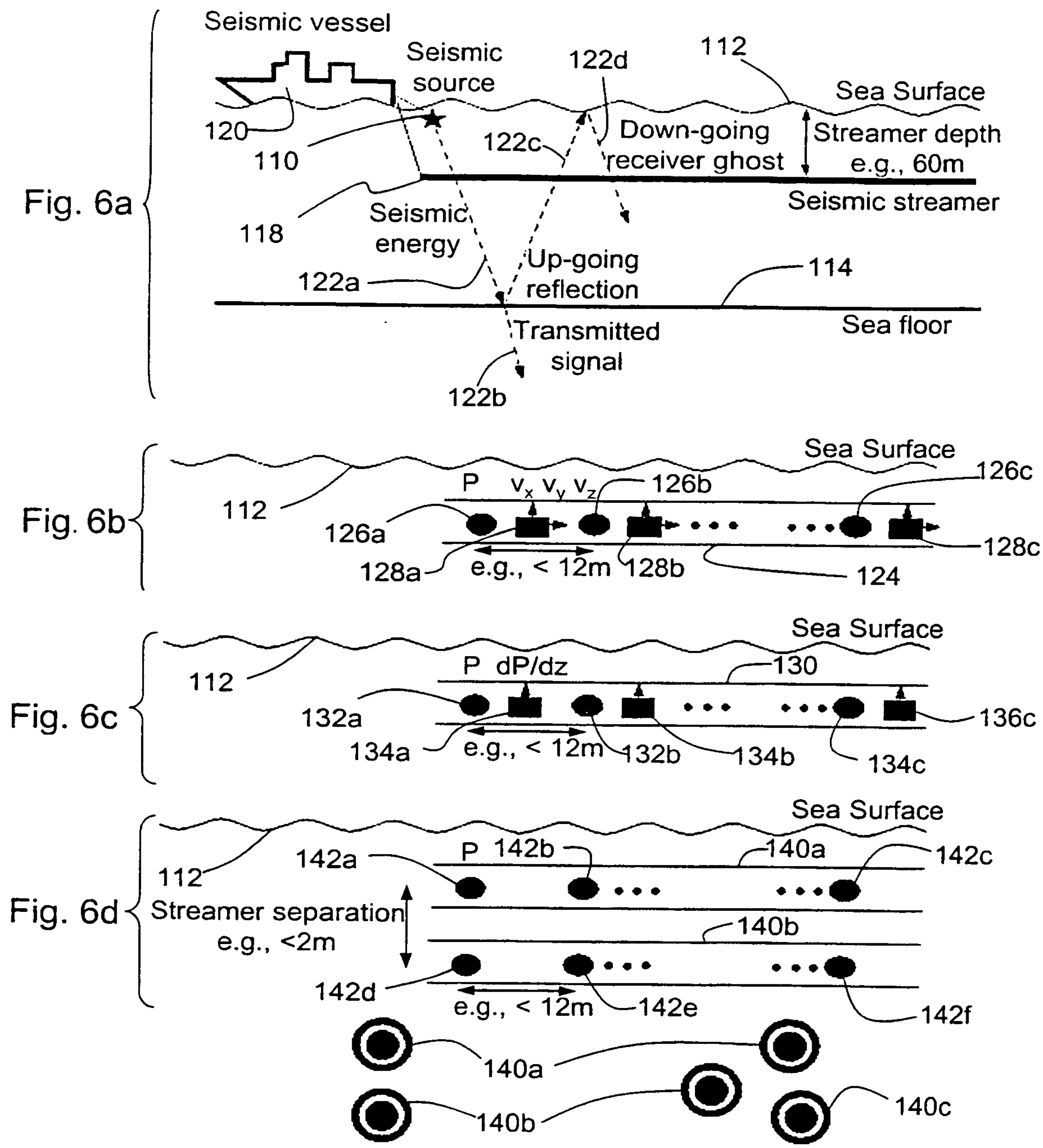


Fig. 6e Fig. 6f

Figures 6a-f

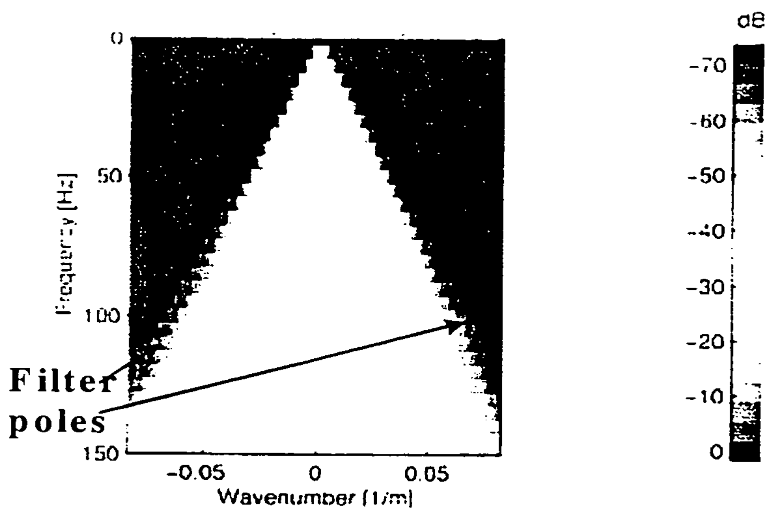

dB
-70
-60
-50
-40
-30
-20
-10
0
0
50
100
150
Frequency [Hz]
Filter poles
-0.05
0
0.05
Wavenumber [1/m]

Figure 7

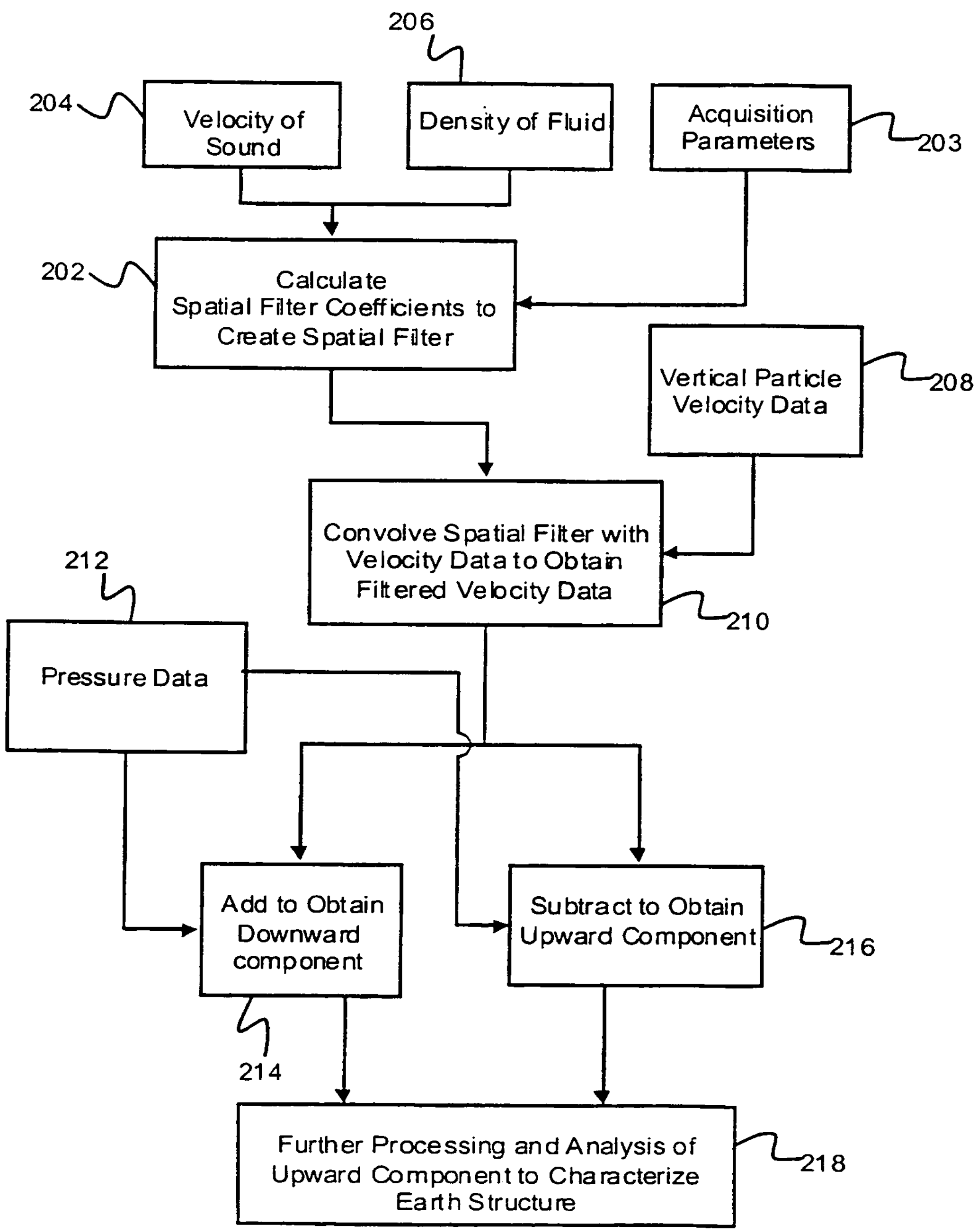

206
204
Velocity of Sound
Density of Fluid
Acquisition Parameters
203
202
Calculate Spatial Filter Coefficients to Create Spatial Filter
Vertical Particle Velocity Data
208
Convolve Spatial Filter with Velocity Data to Obtain Filtered Velocity Data
212
210
Pressure Data
Add to Obtain Downward component
Subtract to Obtain Upward Component
216
214
Further Processing and Analysis of Upward Component to Characterize Earth Structure
218

Figure 8

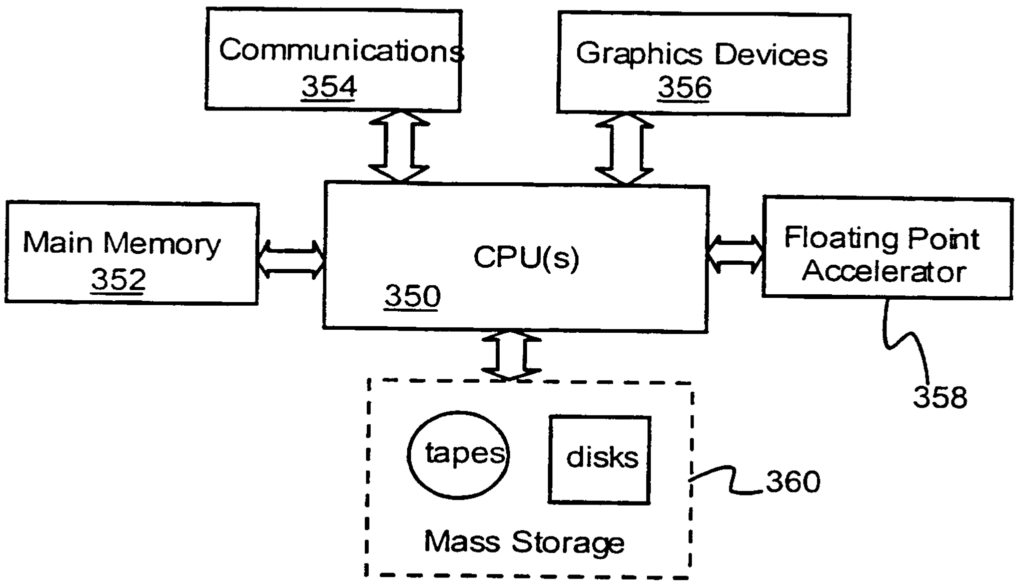

Communications
354
Graphics Devices
356
Main Memory
352
CPU(s)
350
Floating Point
Accelerator
358
tapes
disks
360
Mass Storage

Figure 9

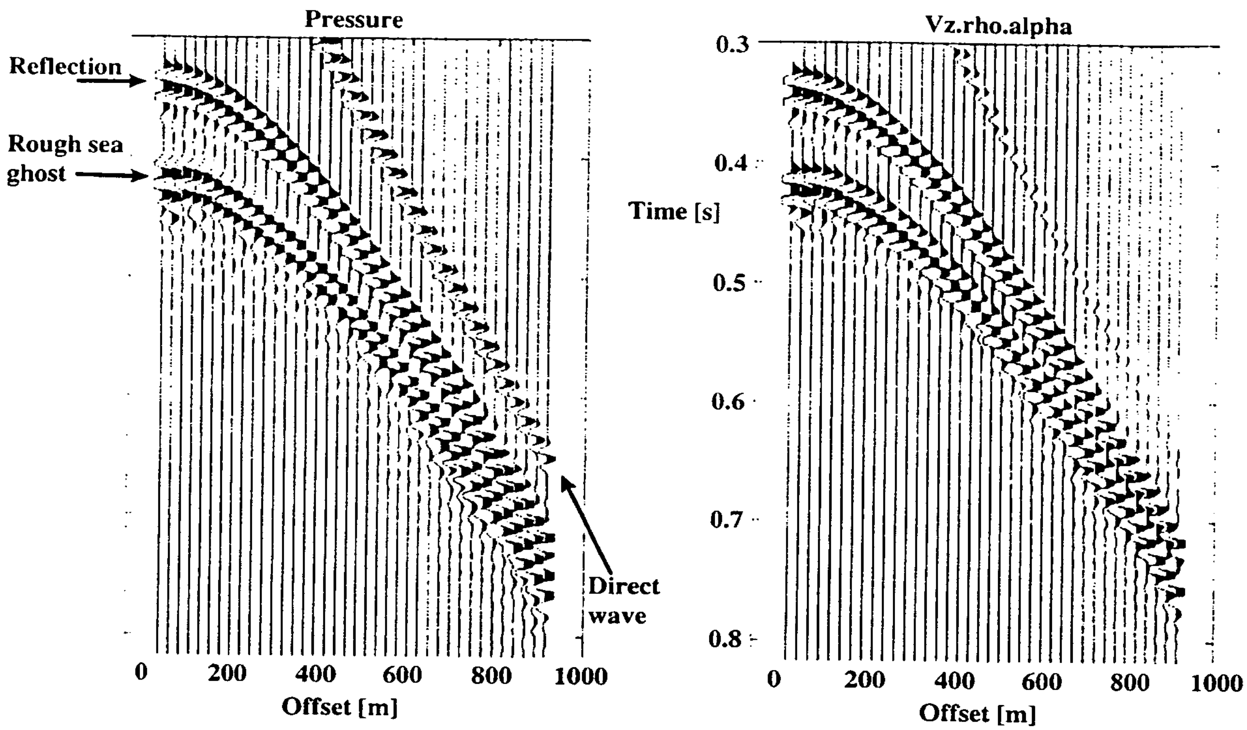

Pressure
Reflection
Rough sea ghost
Direct wave
0
200
400
600
800
1000
Offset [m]
Vz.rho.alpha
0.3
0.4
0.5
0.6
0.7
0.8
Time [s]
0
200
400
600
800
1000
Offset [m]

Figure 10

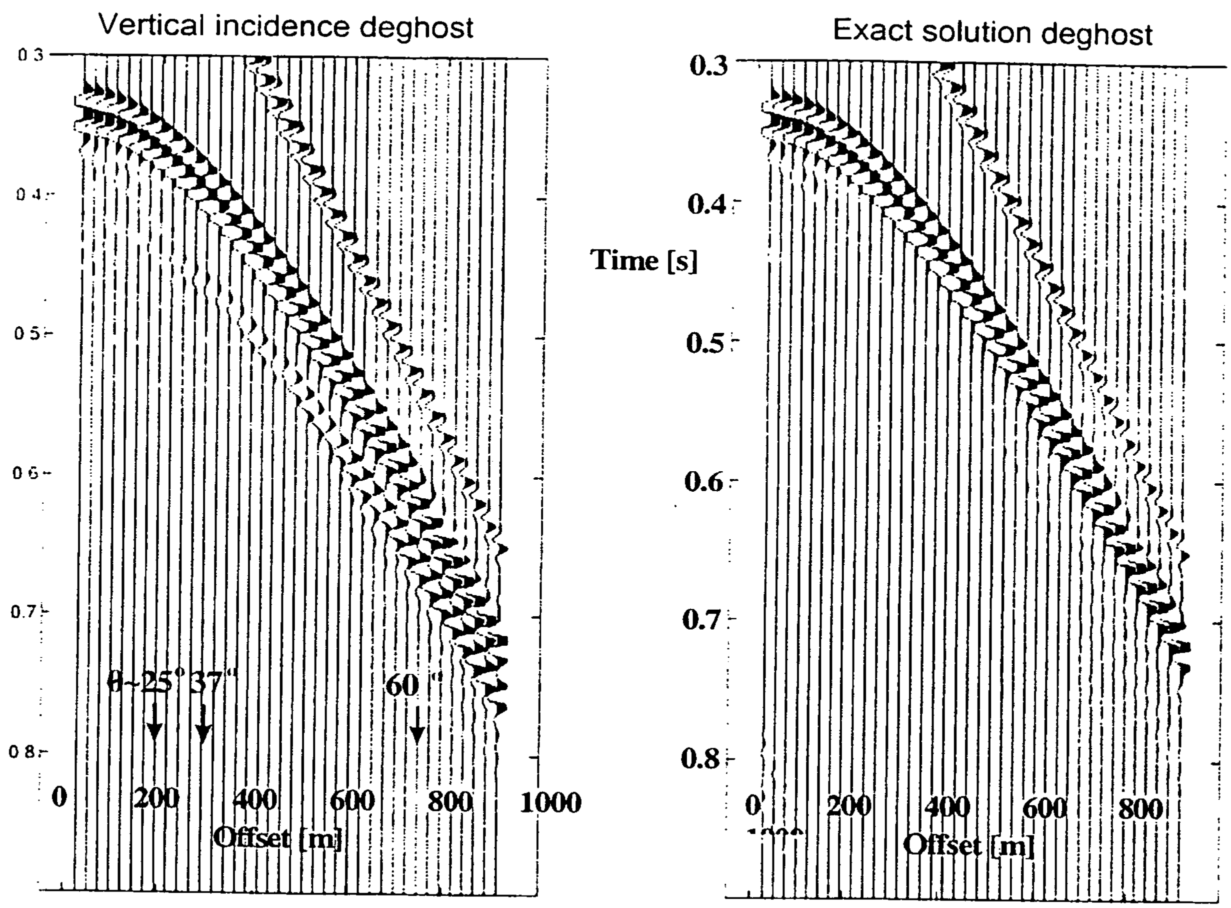

Vertical incidence deghost
Exact solution deghost
0.3
0.4
0.5
0.6
0.7
0.8
Time [s]
θ~25° 37° 60°
0
200
400
600
800
1000
Offset [m]

Figure 11

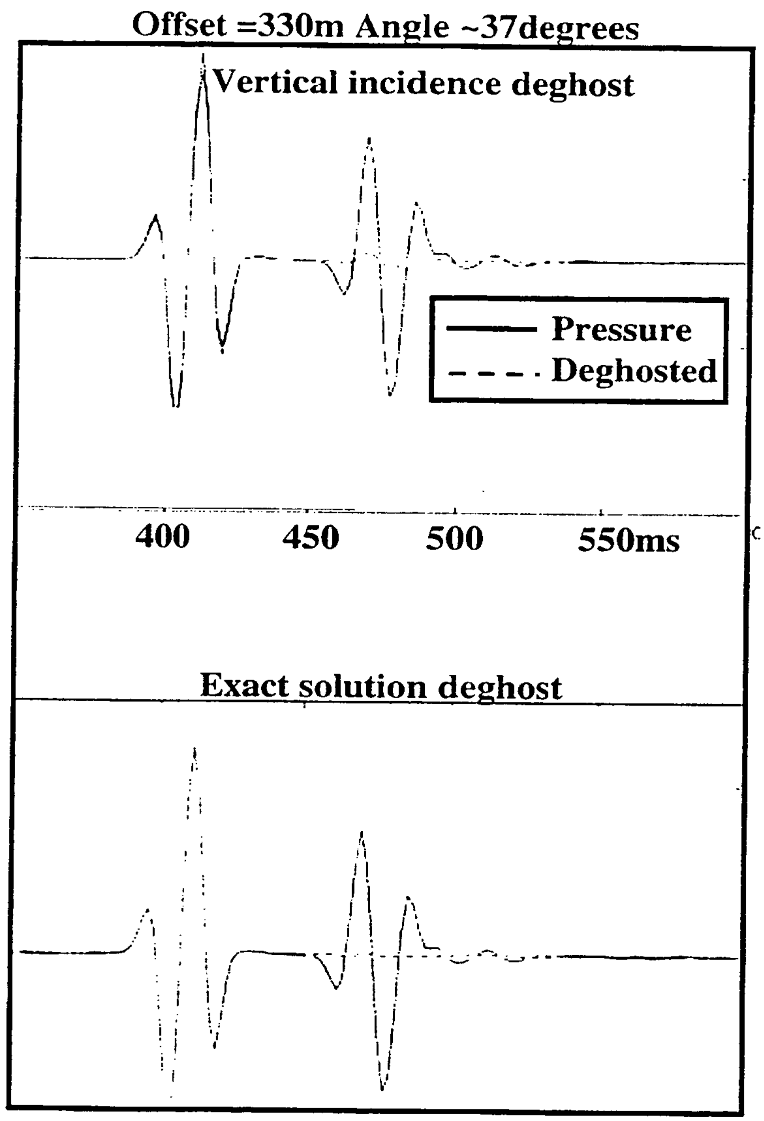

Offset =330m Angle ~37degrees
Vertical incidence deghost
Pressure
Deghosted
400
450
500
550ms
Exact solution deghost

Figure 12

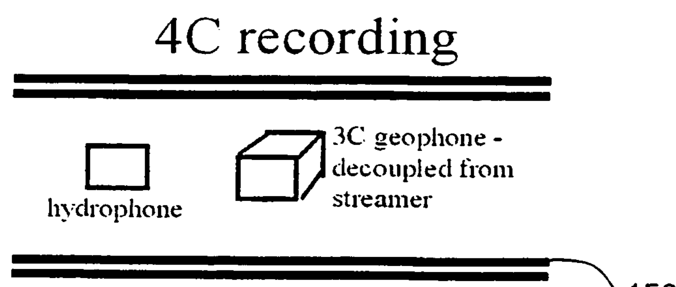


Figure 12a

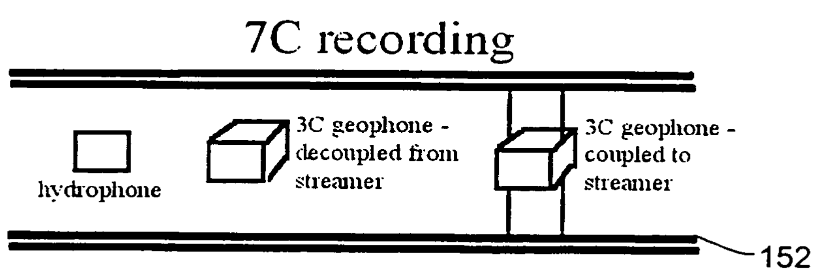


Figure 12b

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G01V 1/36, 1/38

A1

(11) International Publication Number: WO 00/57207

(43) International Publication Date: 28 September 2000 (28.09.00)

(21) International Application Number: PCT/GB00/01074

(22) International Filing Date: 21 March 2000 (21.03.00)

(30) Priority Data:
9906456.0 22 March 1999 (22.03.99) GB

(71) Applicant (*for all designated States except CA FR US*): SCHLUMBERGER HOLDINGS LIMITED [-/-]; P.O. Box 71, Craigmuir Chambers, Road Town, Tortola (VG).

(71) Applicant (*for CA only*): SCHLUMBERGER CANADA LIMITED [CA/CA]; Monenco Place, 24th floor, 801 6th Avenue, S.W., Calgary, Alberta T2P 3W2 (CA).

(71) Applicant (*for FR only*): SERVICES PETROLIERS SCHLUMBERGER [FR/FR]; 42, rue Saint-Dominique, F-75007 Paris (FR).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): ROBERTSSON, Johan, Olof, Anders [SE/GB]; Stasjonsveien 28A, 0772 Oslo (NO). KRAGH, Julian, Edward [GB/GB]; Sudbury Cottage, Cornish Hall End Road, Little Sampford, Essex CB10 2QS (GB). MARTIN, James, Edward [GB/NO]; Brenneveien 95, N-1349 Rykkinn (NO).

(74) Agent: WANG, William, L.; Intellectual Property Law Department, Schlumberger Cambridge Research Limited, High Cross, Madingley Road, Cambridge CB3 0L (GB).

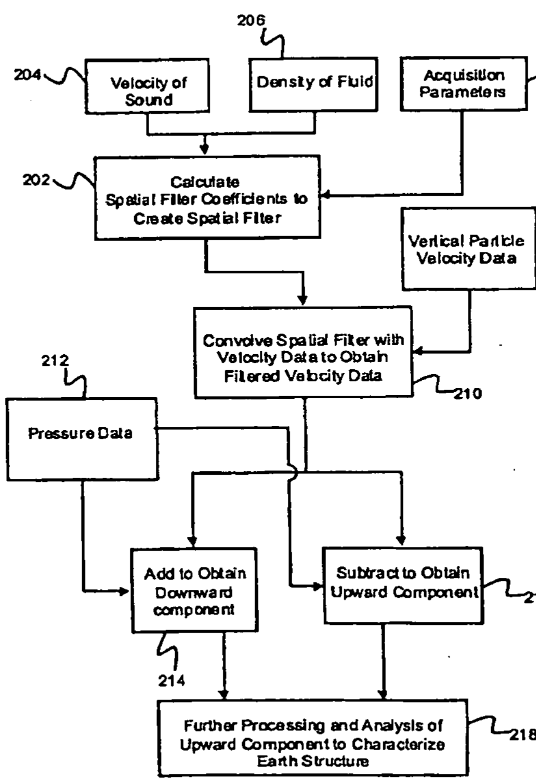
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: METHOD AND SYSTEM FOR REDUCING EFFECTS OF SEA SURFACE GHOST CONTAMINATION IN SEISMIC DATA

(57) Abstract

An improved de-ghosting method and system that utilises multi-component marine seismic data recorded in a fluid medium is disclosed. The disclosed method makes use of two types of data: pressure data, that represents the pressure in the fluid medium, such as sea water, at a number of locations; and vertical particle motion data, that represents the vertical particle motion of the acoustic energy propagating in the fluid medium at a number of locations within the same spatial area as the pressure data. The vertical particle motion data can be in various forms, for example, velocity, pressure gradient, displacement, or acceleration. A spatial filter is designed so as to be effective at separating up and down propagating acoustic energy over substantially the entire range of non-horizontal incidence angles in the fluid medium. The spatial filter is applied to either the vertical particle motion data or to the pressure data, and then combined with the other data to generate pressure data that has its up and down propagating components separated.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania
AM	Armenia
AT	Austria
AU	Australia
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BB	Barbados
BE	Belgium
BF	Burkina Faso
BG	Bulgaria
BJ	Benin
BR	Brazil
BY	Belarus
CA	Canada
CF	Central African Republic
CG	Congo
CH	Switzerland
CI	Côte d'Ivoire
CM	Cameroon
CN	China
CU	Cuba
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
ES	Spain
FI	Finland
FR	France
GA	Gabon
GB	United Kingdom
GE	Georgia
GH	Ghana
GN	Guinea
GR	Greece
HU	Hungary
IE	Ireland
IL	Israel
IS	Iceland
IT	Italy
JP	Japan
KE	Kenya
KG	Kyrgyzstan
KP	Democratic People's Republic of Korea
KR	Republic of Korea
KZ	Kazakstan
LC	Saint Lucia
LI	Liechtenstein
LK	Sri Lanka
LR	Liberia
LS	Lesotho
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Republic of Moldova
MG	Madagascar
MK	The former Yugoslav Republic of Macedonia
ML	Mali
MN	Mongolia
MR	Mauritania
MW	Malawi
MX	Mexico
NE	Niger
NL	Netherlands
NO	Norway
NZ	New Zealand
PL	Poland
PT	Portugal
RO	Romania
RU	Russian Federation
SD	Sudan
SE	Sweden
SG	Singapore
SI	Slovenia
SK	Slovakia
SN	Senegal
SZ	Swaziland
TD	Chad
TG	Togo
TJ	Tajikistan
TM	Turkmenistan
TR	Turkey
TT	Trinidad and Tobago
UA	Ukraine
UG	Uganda
US	United States of America
UZ	Uzbekistan
VN	Viet Nam
YU	Yugoslavia
ZW	Zimbabwe

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01074

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01V1/36 G01V1/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01V

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 486 865 A (RUEHLE WILLIAM H) 4 December 1984 (1984-12-04) abstract; claim 1	1,12,18
P,X	GB 2 333 364 A (GECO AS) 21 July 1999 (1999-07-21) cited in the application	1,12,18
Y	abstract page 5, line 10 -page 6, line 5; figure 4	9,13,19
Y	US 3 747 055 A (GREENE E) 17 July 1973 (1973-07-17) column 1, line 54 -column 2, line 14 column 2, line 54 - line 62 column 8, line 25 -column 9, line 8 abstract; figures 1-6	9,13,19

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 June 2000	07/07/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Bekker, R

1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 00/01074

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	BARR F J ET AL: "ATTENUATION OF WATER-COLUMN REVERBERATIONS USING PRESSURE AND VELOCITY DETECTORS IN A WATER-BOTTOM CABLE" ANNUAL MEETING OF SOCIETY EXPL. GEOPHYS. EXPANDED ABSTRACTS,XX,XX, 1 January 1989 (1989-01-01), pages 653-656, XP000672198 the whole document figures 1-3 ---	1,12,18
A	US 4 979 150 A (BARR FREDERICK J) 18 December 1990 (1990-12-18) cited in the application abstract; figures 1-9,14 column 1, line 41 -column 2, line 31 column 2, line 57 -column 3, line 34 ---	1,12,18
A	AMUNDSEN L ET AL: "EXTRACTION OF THE NORMAL COMPONENT OF THE PARTICLE VELOCITY FROM MARINE PRESSURE DATA" GEOPHYSICS,US,SOCIETY OF EXPLORATION GEOPHYSICISTS. TULSA, vol. 60, no. 1, 1 January 1995 (1995-01-01), pages 212-222, XP000507558 ISSN: 0016-8033 abstract; figure 1 ** formula 20 ** ---	1,2,12, 18
A	GB 2 090 407 A (MOBIL OIL CORP) 7 July 1982 (1982-07-07) abstract; figures 1-5 page 1, left-hand column, line 63 -right-hand column, line 1 ---	1,12,18
A	US 2 757 356 A (HAGGERTY P.E.) 31 July 1956 (1956-07-31) figures 1-7 ---	3-7, 14-17, 20-23
A	US 4 222 266 A (THEODOULOU SAMUEL M) 16 September 1980 (1980-09-16) abstract ---	7,8

-/--

1

INTERNATIONAL SEARCH REPORT

Intei .onal Application No
PCT/GB 00/01074

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	SCHNEIDER W A ET AL: "A new data-processing technique for the elimination of ghost arrivals on reflection seismograms" GEOPHYSICS,US,SOCIETY OF EXPLORATION GEOPHYSICISTS. TULSA, vol. 29, no. 5, 1 October 1964 (1964-10-01), pages 783-805, XP002087819 ISSN: 0016-8033 figures 2,3	18
X	US 5 850 622 A (VASSILIOU ANTHONY A ET AL) 15 December 1998 (1998-12-15) figure 7	24-29

1

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 00/01074

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4486865 A	04-12-1984	BR 8105589 A	18-05-1982
		CA 1157139 A	15-11-1983
		DE 3134325 A	06-05-1982
		FR 2489530 A	05-03-1982
		GB 2083221 A,B	17-03-1982
		SG 78384 G	26-04-1985
		AU 542118 B	07-02-1985
		AU 7407081 A	11-03-1982
		JP 57074676 A	10-05-1982
GB 2333364 A	21-07-1999	FR 2773618 A	16-07-1999
		NO 990153 A	16-07-1999
US 3747055 A	17-07-1973	NONE	
US 4979150 A	18-12-1990	AU 5716490 A	28-02-1991
		CA 2019007 A,C	25-02-1991
		DE 69018161 D	04-05-1995
		DE 69018161 T	07-09-1995
		EG 19158 A	29-02-1996
		EP 0414344 A	27-02-1991
		NO 303033 B	18-05-1998
GB 2090407 A	07-07-1982	US 4380059 A	12-04-1983
		CA 1254297 A	16-05-1989
		DE 3149525 A	08-07-1982
		NO 813463 A,B,	30-06-1982
US 2757356 A	31-07-1956	NONE	
US 4222266 A	16-09-1980	CA 1136255 A	23-11-1982
		GB 2029582 A,B	19-03-1980
US 5850622 A	15-12-1998	CA 2242757 A	14-05-1998
		EP 0873527 A	28-10-1998
		NO 983130 A	07-09-1998
		WO 9820367 A	14-05-1998

WO 00/57207
PCT/GB00/01074

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

To:
WANG, William, L.
Intellectual Property Law
Department
Schlumberger Cambridge Research
Limited
High Cross
Madingley Road
Cambridge CB3 0L
ROYAUME-UNI

PATENTS
DATE RECEIVED 09 OCT 2000
7201 WLW

Date of mailing (day/month/year) 28 September 2000 (28.09.00)	
Applicant's or agent's file reference 57.0326WOPCT	**IMPORTANT NOTICE**

International application No.	**International filing date** (day/month/year)	**Priority date** (day/month/year)
PCT/GB00/01074	21 March 2000 (21.03.00)	22 March 1999 (22.03.99)

Applicant
SCHLUMBERGER HOLDINGS LIMITED et al

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   AU,KP,KR,US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   AE,AL,AM,AP,AT,AZ,BA,BB,BG,BR,BY,CA,CH,CN,CR,CU,CZ,DE,DK,DM,EA,EE,EP,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KZ,LC,LK,LR,LS,LT,LU,LV,MA,MD,MG,MK,MN,MW,MX,NO,NZ,OA,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,TZ,UA,UG,UZ,VN,YU,ZA,ZW
   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on 28 September 2000 (28.09.00) under No. WO 00/57207

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, a **demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

57.0326 WO PCT

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer J. Zahra
Facsimile No. (41-22) 740.14.35	Telephone No. (41-22) 338.83.38

3537646 11.10.00